Nancy Grace Roman Technology Fellowship

Integral Precision Wavefront Correcting Optics for Coronagraphy

Completed Technology Project (2015 - 2016)

Project Introduction

Various forms of coronagraphic instrumentation comprise the largest subset of the future options to directly image exoplanets, both on the ground and in space. Their manipulation of the field and need for precision wavefront control through the use of deformable mirrors (DMs) makes these instruments inherently complex. We propose a new instrument concept and a DM that is purpose built for coronagraphic instrumentation. Many of the relay optics in a coronagraph are only there to accommodate the mandated wavefront control system. High performance deformable mirrors exist, but are largely built for speed and high stroke. This comes at the cost of poor surface figure in the form of uncontrollable spatial frequencies that limit the optical bandwidth the wavefront control system can achieve. The central objectives of changing the way we design an instrument with wavefront control is to reduce the complexity of integrating DMs into the instrument. This will both improve performance and reduce risk for future space-borne instrumentation. The proposed instrument concept presupposes controllable surfaces that can carry their own optical prescription and maintain very high surface quality. A DM with its own nominal optical prescription simplifies its integration into the instrument because any of the powered surfaces can themselves become a deformable mirror. This simplifies the incorporation of multiple DMs, crucial to increasing the discovery space in a coronagraphic image. The proposed instrument concept also has the capacity to improve the controllable bandwidth and decrease the required actuator count per optical element, a major point of risk mitigation for future space-borne instrumentation. With DM prototyping underway, the tasks left in achieving the stated objectives are developing higher actuator count mirrors with hybridized actuation, verifying surface figure, manufacturing DMs that carry optical power, and integrating them into a coronagraphic instrument analog. Since conceptual DM prototypes are underway and demonstrated in the proposal, the concept study year would be used to develop the instrument concept into which such prototypes may be integrated. This will allow us to demonstrate early stages of implementation into a coronagraphic instrument and identify potential risks and complications experimentally. In the wake of the AFTA-WFIRST and Exo-C studies, which use a smaller primary mirror, part of the effort will also keep low-order control in mind. Control of focus is critical for maintaining high contrast at low inner working angles; prior studies have indicated this can require controlling focus at picometer levels. Regulating pressure within the DM controls a pure focus mode with no wavefront residual and no additional moving parts in the optical train. This expands the breadth of the DMs functionality in a coronagraphic instrument as it provides a solution to an as-yet unsolved component of a low-order control system. Simplifying the instrument package and improving the optical quality of the DM ultimately improves image quality and instrument efficiency. This translates to less time for wavefront control, higher achievable bandwidths, and lower integration times. The ferrofluid DM directly reduces mission overhead and improves detection limits. The net result is more time allocated to science and more planetary detections.

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Table of Contents

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

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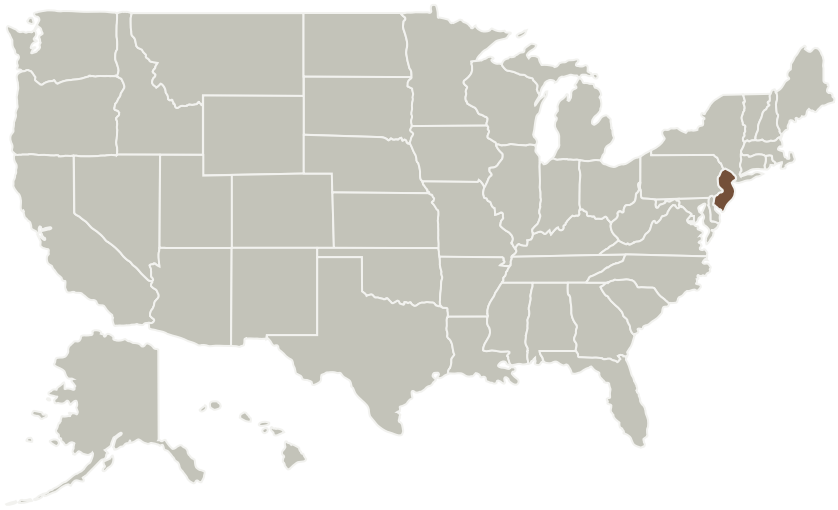
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Princeton University	Supporting Organization	Academia	Princeton, New Jersey

Primary U.S. Work Locations
New Jersey

Project Management

Program Director:
Mario R Perez

Program Manager:
Mario R Perez

Principal Investigator:
Tyler D Groff

Co-Investigators:
Aaron J Lemmer
Jeffrey Friedland

Technology Areas

Primary:

- TX08 Sensors and Instruments
  - TX08.2 Observatories
    - TX08.2.1 Mirror Systems

Target Destination

Outside the Solar System